
ICRP C2
What are « Internal Dose Coefficients » ?
What are « Internal Dose Coefficients »?

A Coefficient is a value that multiplies another value (Cambridge Dictionary)

Allows to transform one quantity into another
What are « *Internal Dose Coefficients* »?

Every dose to biological tissues is « internal »

« *Misuse* » of language

Distinguish doses from external exposure
What are « Internal Dose Coefficients »?

Every dose to biological tissues is « internal »

« Misuse » of language

Distinguish doses from external exposure from doses from internal exposure
ICRP has been active from the early beginning in the field of internal exposure
ICRP has been active from the early beginning in the field of internal exposure.
Internal exposures to radiations are managed by the use of the committed effective dose

\[ e(\tau) = \sum_T w_T \left[ \frac{h_T^M(\tau) + h_T^F(\tau)}{2} \right] \]

Cannot be measured !!
Calculating committed effective dose after internal contamination is a complex procedure
Intake → Deposition in tissues
Biokinetic models

Intake → Deposition in tissues
Generic biokinetic model
HRTM

Extrinsic removal
Inhalation
Exhalation

Respiratory tract
Lymph nodes

WOUND

Skin

Wound
Sweat

Skin

HATM

Ingestion

Alimentary tract

Blood

Liver

Subcutaneous tissue

Direct absorption

Other organs

Kidney

Urinary bladder

Urine

Faeces

Systemic
Biokinetic models

Intake $\rightarrow$ Deposition in tissues $\rightarrow$ Transformations in tissues

Emitted energy (Mev)

Absorbed dose in tissues (Gy)

Equivalent dose in tissues (Sv)

Effective dose (Sv)

Weighting factors for tissues $w_T$ 

Weighting factors for radiations $w_R$

Nuclear data

Phantoms and codes for radiation transport
Intake → Deposition in tissues → Transformations in tissues (Nb) → Emitted energy (Mev) → Absorbed dose in tissues (Gy) → Equivalent dose in tissues (Sv) → Effective dose (Sv)

Biokinetic models

Dosimetric models
Complex procedure, limited to experts

ICRP has defined concepts and tools, to allow non-specialists to perform dose assessment

1. Dose per intake coefficient (DPIC, formerly DPUI)

2. Dose per content function (DPC)
**Intake**

- Deposition in tissues
  - Transformations in tissues (Nb)
    - Emitted energy (Mev)
      - Absorbed dose in tissues (Gy)
        - Equivalent dose in tissues (Sv)
          - Effective dose (Sv)

Weighting factors for tissues $w_T$
Deposition in tissues

Transformations in tissues (Nb)

<table>
<thead>
<tr>
<th>Type</th>
<th>F</th>
<th>M</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPIC</td>
<td>0.2</td>
<td>1.3</td>
<td>12</td>
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<tr>
<td>μSv/Bq</td>
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</table>

For $^{235}$U

Dose = Intake x DPIC
### Dose per Intake coefficients

**Dose per Bq inhaled or ingested**

**Table 10.7. Committed effective dose coefficients (Sv Bq\(^{-1}\)) for the inhalation or ingestion of \(^{85}\)Sr, \(^{89}\)Sr, and \(^{90}\)Sr compounds.**

<table>
<thead>
<tr>
<th>Inhaled particulate materials (5 (\mu)m AMAD aerosols)</th>
<th>Effective dose coefficients (Sv Bq(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-</td>
<td>(^{85})Sr</td>
</tr>
<tr>
<td>Type F, strontium chloride, sulphate and carbonate</td>
<td>3.8E-10</td>
</tr>
<tr>
<td>Type M, fuel fragments, all unspecified forms</td>
<td>5.0E-10</td>
</tr>
<tr>
<td>Type S, FAP, PSL, strontium titanate</td>
<td>6.7E-10</td>
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</tbody>
</table>

**Ingested materials**

<table>
<thead>
<tr>
<th>(f_A)</th>
<th>(^{85})Sr</th>
<th>(^{89})Sr</th>
<th>(^{90})Sr</th>
</tr>
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<tbody>
<tr>
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<td>0.25, all other chemical forms</td>
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<td>8.9E-10</td>
<td>2.4E-08</td>
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</tbody>
</table>

AMAD, activity median aerodynamic diameter; FAP, fused aluminosilicate particles; PSL, polystyrene.

*From ICRP Publication 134, 2016*
ICRP provides dose coefficients for inhalation and ingestion of the most important isotopes and for (almost) every element
General procedures for assessing doses

Intake $\rightarrow$ Deposition in tissues $\rightarrow$ Transformations in tissues (Nb) $\rightarrow$ Emitted energy (Mev) $\rightarrow$ Absorbed dose in tissues (Gy) $\rightarrow$ Equivalent dose in tissues (Sv) $\rightarrow$ Effective dose (Sv)

Nuclear data

Fantoms and codes for particles transport

Weighting factors for radiations $w_R$

Weighting factors for tissues $w_T$

Bioassays
General procedures for assessing doses

Intake → Deposition in tissues → Transformations in tissues (Nb) → Emitted energy (Mev) → Absorbed dose in tissues (Gy) → Equivalent dose in tissues (Sv) → Effective dose (Sv)

Bioassays

DPC function

Weighting factors for tissues $w_T$

Weighting factors for radiations $w_R$

Nuclear data

Fantoms and codes for particles transport

ICRP

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION
### Dose per Content Function $z(t)$

Dose per Bq measured in organs or tissues

Table 12.6. Dose per activity content of $^{85}$Zr in the total body, lungs and in daily excretion of urine (Sv Bq$^{-1}$); 5 µm activity median aerodynamic diameter aerosols inhaled by a reference worker at light work.

| Time after intake (d) | Type F | | Type M | | Type S |
|-----------------------|--------|--------|--------|--------|
|                       | Total body | Lungs | Urine | Total body | Lungs | Urine | Total body | Lungs | Urine |
| 1                     | 4.6E-09    | 2.4E-07 | 6.4E-07 | 3.2E-09    | 3.8E-08 | 5.7E-06 | 4.3E-09    | 4.2E-08 | 1.5E-04 |
| 2                     | 7.1E-09    | 2.6E-07 | 1.7E-06 | 5.9E-09    | 4.0E-08 | 1.3E-05 | 8.0E-09    | 4.4E-08 | 3.5E-04 |
| 3                     | 1.1E-08    | 2.9E-07 | 2.2E-06 | 1.3E-08    | 4.2E-08 | 1.7E-05 | 1.8E-08    | 4.6E-08 | 4.8E-04 |
| 4                     | 1.3E-08    | 3.2E-07 | 2.5E-06 | 2.2E-08    | 4.3E-08 | 1.9E-05 | 3.2E-08    | 4.7E-08 | 5.4E-04 |
| 5                     | 1.4E-08    | 3.5E-07 | 2.8E-06 | 2.9E-08    | 4.5E-08 | 2.1E-05 | 4.2E-08    | 4.8E-08 | 5.9E-04 |
| 6                     | 1.5E-08    | 3.8E-07 | 3.1E-06 | 3.2E-08    | 4.6E-08 | 2.2E-05 | 4.6E-08    | 5.0E-08 | 6.4E-04 |
| 7                     | 1.5E-08    | 4.2E-07 | 3.4E-06 | 3.3E-08    | 4.8E-08 | 2.4E-05 | 4.8E-08    | 5.1E-08 | 6.9E-04 |
| 8                     | 1.6E-08    | 4.6E-07 | 3.7E-06 | 3.4E-08    | 4.9E-08 | 2.6E-05 | 5.0E-08    | 5.2E-08 | 7.5E-04 |
| 9                     | 1.6E-08    | 5.1E-07 | 4.0E-06 | 3.5E-08    | 5.0E-08 | 2.8E-05 | 5.1E-08    | 5.3E-08 | 8.1E-04 |
| 10                    | 1.6E-08    | 5.6E-07 | 4.4E-06 | 3.6E-08    | 5.2E-08 | 3.0E-05 | 5.2E-08    | 5.4E-08 | 8.8E-04 |
| 15                    | 1.7E-08    | 8.8E-07 | 7.0E-06 | 3.9E-08    | 5.7E-08 | 4.1E-05 | 5.7E-08    | 5.9E-08 | 1.3E-03 |
| 30                    | 2.1E-08    | 3.2E-06 | 2.6E-05 | 4.8E-08    | 7.6E-08 | 8.7E-05 | 7.0E-08    | 7.2E-08 | 3.2E-03 |
| 45                    | 2.5E-08    | 9.5E-06 | 7.8E-05 | 5.8E-08    | 9.9E-08 | 1.4E-04 | 8.4E-08    | 8.7E-08 | 5.6E-03 |
| 60                    | 3.0E-08    | 2.1E-05 | 1.7E-04 | 6.9E-08    | 1.3E-07 | 1.9E-04 | 1.0E-07    | 1.1E-07 | 7.7E-03 |
| 90                    | 4.1E-08    | 5.1E-05 | 4.1E-04 | 1.0E-07    | 2.2E-07 | 3.3E-04 | 1.5E-07    | 1.5E-07 | 1.2E-02 |
| 180                   | 1.1E-07    | 2.7E-04 | 2.0E-03 | 2.9E-07    | 1.1E-06 | 1.5E-03 | 4.6E-07    | 4.8E-07 | 3.7E-02 |
| 365                   | 8.2E-07    | 3.3E-03 | 2.4E-02 | 2.3E-06    | 2.6E-05 | 2.6E-02 | 4.4E-06    | 4.7E-06 | 3.4E-01 |
### Dose per Content Function $z(t)$

Dose per Bq measured in organs or tissues

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<tr>
<th>Time after intake (d)</th>
<th>Type F</th>
<th></th>
<th></th>
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<th></th>
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<td>Total body</td>
<td>Lungs</td>
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</table>

*Table 12.6. Dose per activity content of $^{85}$Zr in the total body, lungs and in daily excretion of urine (Sv Bq$^{-1}$); 5 µm activity median aerodynamic diameter aerosols inhaled by a reference worker at light work.*

*From ICRP Publication 134, 2016*
Dose per Content Function $z(t)$

Dose per Bq measured in organs or tissues

Table 12.6. Dose per activity content of $^{95}$Zr in the total body, lungs and in daily excretion of urine (Sv Bq$^{-1}$): 5 μm activity median aerodynamic diameter aerosols inhaled by a reference worker at light work.

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<td>4.7E-06</td>
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</tbody>
</table>

From ICRP Publication 134, 2016
Table 12.6. Dose per activity content of $^{65}$Zr in the total body, lungs and in daily excretion of urine (Sv Bq$^{-1}$); 5 μm activity median aerodynamic diameter aerosols inhaled by a reference worker at light work.

<table>
<thead>
<tr>
<th>Time after intake (d)</th>
<th>Total body</th>
<th>Lungs</th>
<th>Urine</th>
<th>Total body</th>
<th>Lungs</th>
<th>Urine</th>
<th>Total body</th>
<th>Lungs</th>
<th>Urine</th>
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<td>4.8E-04</td>
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<td>4.7E-06</td>
<td>3.4E-01</td>
</tr>
</tbody>
</table>

From ICRP Publication 134, 2016
Replace the former system

Intake

Deposition in tissues

Transformations in tissues (Nb)

Emitted energy (Mev)

Absorbed dose in tissues (Gy)

Equivalent dose in tissues (Sv)

Effective dose (Sv)

Weighting factors for tissues $w_T$

Weighting factors for radiations $w_R$

Fantsoms and codes for particles transport

Nuclear data

Bioassays

Retention function

DPIC
Reference Bioassay function

Predicted activity in organs or tissues for intake of 1 Bq

From ICRP Publication 134, 2016
Main past ICRP publications on these topics

For workers


dose coefficients and ALI for inhalation and ingestion.

**Publication 68 (ICRP, 1994)**

No ALI anymore.

**Publications 54 and 78 (ICRP, 1988, 1997)**

guidance on the design of monitoring programs and the interpretation of results, to estimate doses to workers following radionuclide inhalation or ingestion. Provide predicted values of measured quantities after intake.
Main past ICRP publications on these topics

For the members of the public

  age-specific dose coefficients for inhalation and ingestion for 91 elements, using up-to-date models and latest ICRP recommendations.

  Dose to embryo/fetus and infants
Progress and changes made during this period

In physiology and biokinetic models

- New data on Reference man (ICRP 89, 2002)
- Human Alimentary Tract Model (ICRP 100, 2006)
The Human alimentary tract model

The former model
The Human alimentary tract model (2006)
Progress and changes made during this period

In physiology and biokinetic models

- New data on Reference man (ICRP 89, 2002)
- Human Alimentary Tract Model (ICRP 100, 2006)
- New element specific systemic models, physiologically realistic
The former model (ICRP 1994, 1997)

The new model
ICRP Publication 137, In Press

Three subsystems:
- circulating inorganic iodide;
- thyroidal organic iodine
- extrathyroidal organic iodine.
Systemic model for Strontium

The former model (ICRP 1989)

The new model
ICRP Publication 134, 2016
Progress and changes made during this period

In physiology and biokinetic models

- New data on Reference man (ICRP 89, 2002)
- Human Alimentary Tract Model (ICRP 100, 2006)
- New element specific systemic models, physiologically realistic
- More realistic treatment of the biokinetics of radionuclide daughters
- New data supporting update of the Human Respiratory Tract Model
Particle transport model (ICRP 66 HRTM)

Anterior
nasal

Naso-oropharynx-
larynx

Bronchi

Bronchioles

Alveolar
interstitial

Extrathoracic

Environment

Thoracic

GI tract

Clearance
rates (d\(^{-1}\))

LN\(_{ET}\) 0.001 ET\(_{seq}\)

LN\(_{TH}\) 0.01 BB\(_{seq}\)

bb\(_{seq}\) 0.01

bb\(_2\) 0.01

bb\(_1\) 0.00002

AI\(_3\) 0.0001

AI\(_2\) 0.001

AI\(_1\) 0.02

ET\(_1\) 1

ET\(_2\)' 100

ET\(_{seq}\)

BB\(_2\) 0.03

BB\(_1\) 0.03

bb\(_2\) 0.03

bb\(_1\) 0.001

bb\(_1\) 0.001

bb\(_1\) 0.02

LN\(_{TH}\) 0.01

BB\(_{seq}\) 0.01

BB\(_1\) 0.03
Particle transport model (ICRP 103)

Anterior

nasal

Posterior

nasal-

pharynx-

larynx

Extrathoracic

ET

ET

ET

ET

ET

LN

ET

ET

ET

ET

ET

BB

BB

BB

bb

bb

bb

INT

ALV

Thoracic

Oesophagus

Environment

Revised

HRTM
## Default parameter values

**Type F, M, S**

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<thead>
<tr>
<th>Type</th>
<th>ICRP 66</th>
<th>$f_r$</th>
<th>$s_r (d^{-1})$</th>
<th>$s_s (d^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>100</td>
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<tr>
<td>OIR</td>
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<td>0.01</td>
<td>3</td>
<td>0.0001</td>
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Element-specific values for $s_r$. Range from 0.4 to 100 $d^{-1}$
## Example of Uranium absorption

<table>
<thead>
<tr>
<th>Compound</th>
<th>Absorption parameter values</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Default Type F</strong> (UF6, U-TBP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uranyl nitrate, UO$_2$(NO$_3$)$_2$</td>
<td>0.8</td>
<td>(F/M)</td>
</tr>
<tr>
<td>Uranium peroxide hydrate</td>
<td>0.8</td>
<td>(F/M)</td>
</tr>
<tr>
<td>Ammonium diuranate, ADU</td>
<td>0.8</td>
<td>(F/M)</td>
</tr>
<tr>
<td><strong>Default Type M (UF4)</strong></td>
<td></td>
<td>(M/S)</td>
</tr>
<tr>
<td>Uranium Octoxide U$_3$O$_8$;</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Uranium dioxide</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Default Type S</strong></td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>
Progress and changes made during this period

In physiology and biokinetic models
  • New data on Reference man (ICRP 89, 2002)
  • Human Alimentary Tract Model (ICRP 100, 2006)
  • New element specific systemic models, physiologically realistic
  • More realistic treatment of the biokinetics of radionuclide daughters
  • New data supporting update of the Human Respiratory Tract Model

In dosimetry and monitoring
  • Development of adult reference computational phantom, based on the new ref man (ICRP 110, 2009)
  • New skeletal dosimetry (ICRP 116, 2010)
  • Revised nuclear decay data (ICRP 107, 2008)
  • Concept of dose per content
Progress and changes made during this period

In ICRP recommendations

• Adoption of the use of realistic phantoms (ICRP 103, 2007)
• Changes in weighting factors (ICRP 103, 2007)
• Changes in calculation of equivalent dose (ICRP 103, 2007)
Progress and changes made during this period

These new data and recommendations supported a revision of the past reports and provision of new dose coefficients with guidance on monitoring programs and data interpretation

Done for external dosimetry (ICRP 116, 2010)
Need to be done for internal dosimetry
Revision of the reports on internal exposure

Division of the work in two parts:

- Revision of models and dose coefficients for workers (OIR series)

- Revision of models and dose coefficients for members of the public (EIR series,..)
The OIR series
5 volumes

OIR Part 1  (ICRP Publication 130, 2015)

• Control of occupational exposures to radionuclides
• Biokinetic and dosimetric models
• Methods of individual and workplace monitoring
• Monitoring programmes
• General aspects of retrospective dose assessment
For each element section:

- Chemical forms in the workplaces
- Principal radioisotopes, physical half-lives and decay modes
- Review of data on inhalation, ingestion and systemic biokinetics
- Structure of biokinetic models and parameter values
- Monitoring techniques and typical detection limits
- Dose coefficients, reference bioassays functions and dose per content functions in printed document and/or electronic annexes
The OIR series
5 volumes

OIR Part 2  ICRP Publication 134
Hydrogen (H), Carbon (C), Phosphorus (P), Sulfur (S), Calcium (Ca), Iron (Fe), Cobalt (Co), Zinc (Zn), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo) and Technetium (Tc).

OIR Part 3
Ruthenium (Ru), Antimony (Sb), Tellurium (Te), Caesium (Cs), Barium (Ba), Iridium (Ir), Lead (Pb), Bismuth (Bi), Polonium (Po), Radon (Rn), Radium (Ra), Thorium (Th) and Uranium (U).

OIR Part 4
Lanthanides series, actinium (Ac), protactinium (Pa) and transuranic elements

OIR Part 5
Fluorine (F), Sodium (Na), Magnesium (Mg), Potassium (K), Manganese (Mn), Nickel (Ni), Selenium (Se), Molybdenum (Mo), Technetium (Tc) and Silver (Ag) and most of the others

ICRP
INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION
OIR Data viewer
The EIR series
4 volumes

EIR Part 1 (in Progress)
Same information and data for every element currently described in OIR P2 to 4 (plus Ag, Ni, Se)

EIR Part 2
Same information for every other element

EIR Part 3
Breast-feeding Infant Internal Dose Coefficients for Maternal Intakes

EIR Part 4
*In utero* Internal Dose Coefficients for Maternal Intakes
Comparison of dose coefficients between ICRP 68 and OIR P2
Comparison of dose coefficients between ICRP 68 and OIR P3
The authors of this work

The membership of the Task Group 95 on Internal Dosimetry (IDC)

Members:

F Paquet (Chair)    E Blanchardon    R W Leggett
M R Bailey          G Etherington    T P Fell
V Berkovski

Corresponding Members:

E Ansoborlo    D Gregoratto    M Puncher
L Bertelli      J Marsh       T Smith
E Davesne       D Melo        G Ratia
A Giussani      D Nosske

and ..

the CPRT (TG 96 )and the committee 2 members ...